Force and Motion in Our World

Distance and Speed

Measurement and Calculations

Units

Units identify what a specific number represents. For example, the number 42 can be used to represent 42 miles, 42 kilometers, 42 pounds, or 42 elephants. Without the units attached, the number is meaningless. The information is incomplete.

While there are many units systems, we use the SI units (Système International d'Unités).

The metric system (our version of SI) is designed to keep numbers small by converting to similar units by factors of 10.

Prefixes are added in front of a base unit to describe how many factors of 10 the unit has changed.

Base units of measurement are generally described by one letter:

- m – meter (length)
- s – second (time)
- g – gram (mass) *The base unit for mass is actually the kg (kilogram)
- L – litre (volume)

Derived units are combinations of base units. For example, speed is measured in m/s.

Metric Prefixes

See handout of prefixes.

Converting Units

Multiply by One:

- Multiply the measurement by a fraction that equals 1
- The fraction will contain the old unit and the new unit.
- The fraction must cancel out the old unit. (follow the rule that tops and bottoms cancel out)

Ex. Convert 24mm into m.

Ex. Convert 23 km to cm.

Ex. Convert 15.0 m/s into km/h.

The Sanity Test

After any calculation or problem, stop, take a deep breath, and look at your answer. Does your answer make sense?

Imagine you are calculating the number of people in a classroom. If the answer you got was 1 000 000 people, you would know it was wrong – that's an insane number of people to have in a classroom. That's all a sanity check is: is your answer insane or not?

In using the sanity test, it helps to know typical values of things.

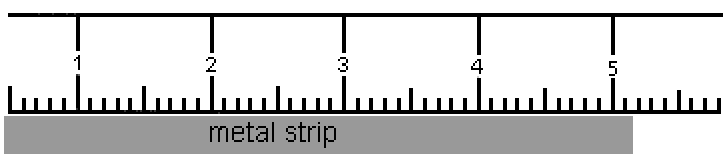
Accuracy vs. Precision

Accuracy is to the extent that a measurement agrees or compares with an accepted value or standard. A very accurate measure of boiling water might be 99.8°C, because it would be compared to the standard of 100°C.

The difference between an observed or measured value and a standard is known as error, and is sometimes written as a percentage.

The accuracy of a measuring instrument depends on how well it compares to an accepted standard, and it should be checked regularly. A known 500.0 g mass should show that same reading on a balance. If it doesn't, the balance should be re-calibrated.

If you were measuring a piece of metal with a ruler (like below), you would get a more exact measurement by using the side graduated in mm (the bottom of the ruler).

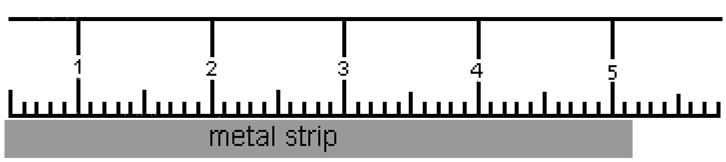


Precision is the degree of exactness that measurement can be reproduced. The precision of a measuring tool is limited by the graduations or divisions on its scale. In other words, you will have a more precise measurement of the metal strip above by using the graduations on the bottom of the ruler (mm) rather than the top (cm).

The precision of an instrument is indicated by the number of decimal places used. For example, 5.14 cm is more precise than 5.1 cm.

Significant Figures

When measuring, the precision is limited by the device - - the number of digits is also limited. Valid digits are called significant digits or significant figures. Significant digits consist of all digits known with a certainty plus the first digit that is uncertain.



The strip above is somewhere between 5.1 and 5.2 cm. We would state that the length is 5.14 cm. The last digit is an estimate (uncertain), but it is still valid and considered to be significant. There are **3 significant digits** in this measurement; the 5 and 1 are known and the 4 is an estimate.

If the strip was dead on the 5.1 graduation, we should record this as 5.10 cm and we would have 3 significant digits.

Rules for Significant Figures

All digits written in scientific notation are significant.

There are 2 rules for determining the number of significant figures.

Decimal Rule

Use this rule when the measurement contains a decimal. Count the numbers from left to right beginning at the first non-zero number.

Ex.

0.001234	0.123400	1240.
1.234	12340.0	1.234×10^{-3}

Non-decimal rule

Use this rule when the measurement **does not** contain a decimal. Count the numbers from right to left beginning at the first non-zero number.

Ex.

1234	0.123400	12340.
102340	12340	100002

Operations with Significant Digits

Adding and Subtracting

The final answer cannot be more precise than the least precise measurement. In other words, the answer must have as few decimal places as the number with the fewest decimal places being added or subtracted.

Ex:

3.414 s + 10.02 s + 58.325 s + 0.000 98 s	1884 kg + 0.94 kg + 1.0 kg + 9.778 kg
2104.1 m - 463.09 m	2.326 hr - 0.104 08 hr

Multiplying and Dividing

Look at the number with the least amount of significant digits. Round the final answer to contain this many significant digits.

Ex.

10.19 cm × 0.013 cm	140.01 cm × 26.042 cm
80.23 m ÷ 2.4 s__	4.301 kg ÷ 1.9 cm^3 _

Multiple Operations

When a series of calculations is performed, each interim value should not be rounded before carrying out the next calculation. The final answer should then be rounded to the same number of significant digits as contained in the quantity in *the original data* with the lowest number of significant digits.

For example, in calculating (1.23)(4.321) ÷ (3.45 – 3.21), three steps are required:

3.45 – 3.21 = 0.24

(1.123)(4.321) = 5.21483

5.31483 ÷ 0.24 = 22.145125

The answer should be rounded to 22.1 since 3 is the lowest number of significant digits in the original data. The interim values are not used in determining the number of significant digits in the final answer.

Defined Equations

Relationships between variables can be expressed using words, pictures, graphs or mathematical equations. A defined equations is a mathematical expression of the relationship between variables

Ex. Mass and Energy are related by the speed of light

$$E = mc^2$$

Defined equations can be manipulated to solve for any of the variables using the same principles from math.

There are 2 rules that must be followed to isolate a variable:

1) It must be alone
2) It must be on top (numerator)

Ex. Solve $E = mc^2$ for m.

Ex. Solve $d = \frac{m}{v}$ for v.

Relating Speed to Distance and Time

Speed is a rate of change – it is how fast something is moving.

Average speed is total distance travelled divided by the time it took for the trip.

$v_{av} = \frac{\Delta d}{\Delta t} = \frac{d_2 - d_1}{t_2 - t_1}$	Where v = average speed d1 = initial position d2 = final position Δt = total time taken to travel the distance

Δ is the fourth capital letter in the Greek alphabet. It is called "delta" and is read as "change in" and is always the final quantity minus the initial quantity.

For example, $\Delta d = d_2 - d_1$.

Distance is the amount of space between two objects or points. It needs no reference frame. You measure the distance between two objects by measuring their separation. It simply refers to the length (or magnitude) between the two objects. Direction does not matter.

Common units for distance:

Time is the duration between two events.

Common units for time:

Common units for speed:

Ex. A trip to Calgary is 758 km. If you were to complete the trip in 7.25 h, what was you speed?

Ex. Driving at 95 km/h, how long would it take you to travel 2376 km?

Ex. Janna has a summer job helping with bison research. She notes that they graze at an average speed of about 110 m/h for about 7.0 h/day. What distance, in kilometers, will the herd travel in two weeks?

Instantaneous speed is the speed at which an object is travelling at a particular instant. It is not affected by previous speeds, future speeds, or how long it has been travelling for.

Ex.

Constant speed, also called uniform motion, is when the speed of an object remains the same over a period of time. The average speed of an object is the same as its instantaneous speed when it is travelling at a constant speed.

Ex.

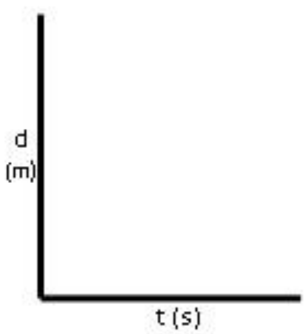
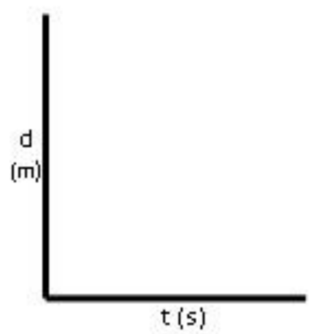
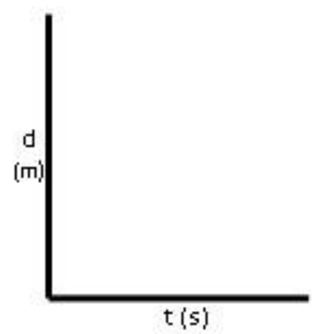
Graphing

See Nelson Science 10 pp. 699 - 701

Distance-Time Graphs

We can represent speed with words (fast, slow), numbers (32 km/h) and we can also represent it visually with a graph.

Speed can be represented on a distance vs. time graph. The slope of the graph is the speed. Constant (uniform) motion is given by a straight line on the graph. Curves indicate non-uniform motion. Zero slope represents no motion.

No speed	**Constant Speed**	**Changing Speed (Acceleration)**
		

Ex. Describe the motion in the following graph: